APPENDIX D
WATER MANAGEMENT PLAN

ATLANTIC RIM INTERIM DRILLING PROJECT
RED RIM PROPOSED ACTION

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INTRODUCTION AND GEOGRAPHIC SETTING

Anadarko E&P Company (AEPC) and Warren E&P, Inc. (Warren), collectively referred to as "the Companies," propose to explore for and potentially develop coal bed natural gas (CBNG) resources in the Red Rim area (Project Area) of the western portion of Carbon County, Wyoming (Figures 1-1 and 2-1 of the EA). Exploration and development in the Project Area would occur as part of the Red Rim Plan of Development (POD) for the Atlantic Rim Interim Drilling Project. Wells in the Project Area would be located 8 miles southwest of Rawlins, Wyoming, along Carbon County Road 605 (Twentymile Road), which intersects Interstate 80 (I-80) near Rawlins.

The Project Area lies within the Great Divide Basin. The Continental Divide splits around the Great Divide Basin, and isolates it as a closed basin. Therefore, any water entering the basin is contained within it.

A water management plan (WMP) must be prepared and approved for each individual POD under the Atlantic Rim interim drilling policy. This WMP for the Red Rim POD addresses handling of produced water during testing and production of the Red Rim gas wells. This project consists of nine proposed exploratory wells and seven existing wells. Of the nine proposed well locations, five would be on surface ownership lands administered by the Bureau of Land Management (BLM) Rawlins Field Office (RFO) and would develop federal minerals. One proposed well would be located on surface ownership lands administered by the RFO and would develop minerals owned by the State of Wyoming. The remaining proposed wells (three) would be located on fee lands and would develop fee minerals. There are currently seven gas wells on fee surface and minerals in the Red Rim Project Area that are existing or authorized. **Table D-1** summarizes the existing and proposed wells addressed in this WMP and will be updated if the Companies propose additional development.

Under alternative 1, all produced water from these wells would be discharged to ephemeral tributaries of Hadsell Draw on fee lands within the closed Great Divide Basin. Under alternative 2 waters from the federal leases would be re-injected (about 32% of the produced water) and water from fee and state leases would be surface discharged under both alternative 2 and 3. Under all alternatives, surface discharge of produced water would comply with terms, conditions, and monitoring requirements of a National Pollutant Discharge Elimination System (NPDES) permit issued by the Wyoming Department of Environmental Quality (WDEQ).

TABLE D-1 RED RIM PROJECT

Proposed Gas Wells			
Lease Number	**Well Name**	**Well Number**	**Location**
WYW-149261	AR Federal[1]	2089 NE20	T20N R89W Section 20 NENE
	AR Federal[1]	2089 SE20	T20N R89W Section 20 SESE
	AR Federal[1]	2089 SW20	T20N R89W Section 20 SWSW
WYW-150410	AR Federal[1]	2089 NW28	T20N R89W Section 28 SENW
	AR Federal[1]	2089 NE28	T20N R89W Section 28 NWNE
FEE/STATE LEASES	AR Fee	2089 NE16	T20N R89W Section 16 SWNE
	AR Fee	2089 SW16	T20N R89W Section 16 NESW
	AR State[1]	2089 SE16	T20N R89W Section 16 NWSE
	AR Fee	2089 NE29	T20N R89W Section 29 NENE
Existing or Authorized Gas Wells[2]			
Lease Information	**Well Name**	**Well Number**	**Location**
FEE LEASES	AR Fee	2089 NE21	T20N R89W Section 21 NENE
	AR Fee	2089 NW 21	T20N R89W Section 21 NENW
	AR Fee	2089 SW21	T20N R89W Section 21 NESW
	AR Fee	2089 SE21	T20N R89W Section 21 NESE
	AR Fee	2089 NW29	T20N R89W Section 29 SENW
	AR Fee	2089 SW29	T20N R89W Section 29 SWSW
	AR Fee	2089 SE29	T20N R89W Section 29 SESE
Proposed Injection Well			
FEE LEASE	AR Fee	29I	T20N R89W Section 29 NENE
Existing or Authorized Injection Well			
FEE LEASE	AR Fee	21I	T20N R89W Section 21 NENE
Proposed Facilities[2]			
FEE LEASE	Conditioning Facility	Bountiful	T20N R89W Section 29 NENE
FEE LEASE	Outfall	Bountiful 001 (RR-D1)	T20N R89W Section 29 SWNE
Existing or Authorized Facilities[3]			
Lease Information	**Site Type**	**Name**	**Location**
FEE LEASE	Conditioning Facility	Abundance	T20N R89W Section 21 NENE
FEE LEASE	Outfall	Abundance 002 (RR-D2)	T20N R89W Section 21 NENE
FEE LEASE	Outfall	Abundance 003 (RR-D3)	T20N R89W Section 21 NENE
FEE LEASE	Compressor Station	Red Rim	T20N R89W Section 21 SESE

Note: [1] BLM surface ownership lands

[2] Facilities requiring authorization from BLM prior to construction under alternatives 2.

[3] Facilities requiring no authorization from BLM prior to construction or development under all alternatives.

DESCRIPTION OF WATERSHED

The Project Area is located within the Great Divide Closed Basin, Hydrologic Unit Code (HUC) 14040200. Surface waters near the Project Area include the ephemeral to intermittent Separation Creek, ephemeral tributaries including Hadsell Draw, and several unnamed ephemeral channels and constructed ponds.

The drainage area of Hadsell Draw is 27 square miles. The average slope is between 4 to 6 percent throughout this low-gradient drainage basin. This drainage consists of undisturbed rangeland and is grazed at different times of the year by domestic livestock and resident wildlife. A mixture of sagebrush and native grasslands characterizes the drainage basin. Hadsell Draw is a sinuous, well-defined, and vegetated channel. The tributaries — Bountiful and Abundance — are less sinuous than the main stem and are characterized by vegetated channels. The floodplain and tributary system of Hadsell Draw is well developed, with no observed significant erosion features along established channels (i.e. headcuts greater than 1ft. in drop).

The first major tributary to Hadsell Draw is Abundance Tributary, and the second is Bountiful Tributary. The drainage area is 3.55 square miles for the Abundance Tributary and 0.93 miles for the Bountiful Tributary. The average slope is between 5 to 7 percent throughout the low-gradient drainage basin of Abundance Tributary, and the average slope is between 7 to 9 percent for Bountiful Tributary. The drainages consist of mostly undisturbed rangeland, grazed at different times of the year by domestic livestock and resident wildlife. A mixture of sagebrush and native grasslands characterizes each drainage basin. Abundance and Bountiful Tributaries exhibit sinuous, and vegetated channels, whereas side channels to these tributaries are not sinuous, although they are vegetated. The floodplain and tributary systems are well developed, with no significant erosion features (i.e. headcuts greater than 1ft. in drop) along established channels. However, there are many small erosional features due to grade changes in the channel or lateral adjustments.

There are no designated floodplains within the Project Area. No wetlands have been identified within the Project Area. The principal riparian habitat consists of a narrow band of vegetation along intermittent Hadsell Draw and its tributaries. This vegetation is mostly moisture tolerant grasses, sedges and rushes. Land use within and adjacent to the Project Area includes cattle grazing, wildlife habitat, oil and gas exploration, and dispersed outdoor recreation.

The average annual total precipitation collected at Rawlins, Wyoming from March 6, 1951, to March 31, 2003, is 9.2 inches (WRCC 2003). Precipitation is greatest during the summer, although minor peaks occur in April, May, and October.

PRODUCED WATER DISPOSAL

Three discharge points are proposed for the water produced from the Red Rim wells, with two located on Abundance Tributary and one on Bountiful Tributary. The proposed discharge points are shown in Figure 2-1 of the EA (Project Map)**.** Data from the nearby existing wells indicate an average maximum flow rate per well of 32 gallons per minute (gpm). All calculations for this WMP therefore assume an average flow rate of 32 gpm for each well. It is further assumed that all wells in the Project Area will produce similar flow rates. A tabulation of the approximate existing, proposed, and potential discharges within Hadsell Draw is shown in **Table D-2**. The wells proposed in the Project Area would be piped to the discharge points proposed in the Companies' National Pollutant Discharge Elimination System (NPDES) permit application. Flow rates for Hadsell Draw and its tributaries may vary at different times of the year, and the figures presented are best estimates for the outfalls. The wells in the Project Area addressed in this WMP will add approximately 1.14 cubic feet per second (cfs) to the natural channel of Hadsell Draw under alternative 1 and 0.78 cfs under alternatives 2 and 3. Under full development, reasonably foreseeable future actions in the Red Rim POD could include a total of 24 wells. The flow estimated for the full development scenario in the Hadsell Draw watershed is 1.71 cfs for alternative 1 and 1.16 cfs for alternative 2 and 3, assuming the same distribution of federal leases and other leases.

TABLE D-2 EXISTING AND PROPOSED DISCHARGE

Watershed Name	Number of Existing or Authorized Gas Wells	Number of Proposed Gas Wells[1]	Possible Maximum Number of Gas Wells[2]	Existing and Proposed Discharge (gpm)	Maximum Discharge with Watershed Development [3] (gpm)
Bountiful Tributary to Hadsell Draw (Outfall RR-D1)	3	3	7	192	224
Abundance Tributary to Hadsell Draw (Outfalls RR-D2 or RR-D3)	4	6	17	320	544
Total Discharge to Hadsell Draw	7	9	24	512	768

[1]Wells may be connected to more than one discharge, increasing the total number of proposed wells discharging to a specific outfall.
[2]Based on a maximum of 24 wells per POD under the interim drilling policy.
[3]Discharge from maximum development of the Red Rim POD.

Stormwater discharges during construction would be managed in accordance with a stormwater permit issued by the WDEQ.

BENEFICIAL USE OF PRODUCED WATER

Produced water from the Red Rim wells could be available for potential beneficial use on the landowner's ranch. The landowner's priority is to provide additional watering facilities for various livestock and wildlife on the ranch. The Companies have therefore agreed to install five stock tanks at various locations around the ranch. The location of these stock tanks is illustrated in Figure 2-1 of the EA (Project Map)**.** A stock tank will be installed at each outfall, and will be allowed to overflow to the ephemeral drainages in accordance with an approved NPDES permit. The remaining two dispersed stock tanks, located northeast of the proposed AR State 2089 NE 16 well, and south of the proposed AR Federal 2089 NE 28 well, will contain a small portion of the water produced from gas wells (about 8.1 acre-feet/year per well) for use by livestock and wildlife. This water will be piped into tire tanks with shut-off valves that would not discharge produced water onto the surface at these locations.

In addition to installing the stock tanks, the Companies have agreed to permit and upgrade an existing reservoir. Abundance Reservoir, located in the NESE of Section 16 in T20N R89W will be upgraded with an outlet structure and permitted through the Wyoming State Engineers Office (WSEO) as a stock pond. The reservoir will be designed in accordance with WSEO standards to accommodate the proposed discharge from the wells. This reservoir is discussed in detail in a later section.

Produced water may be utilized as make-up water for nearby drilling and completion operations. Any water produced during drilling or well completing would be contained on each drilling location in the reserve pit. During well testing, water produced from the Mesaverde aquifer will be collected on location in closed tanks and trucked to an authorized disposal facility until authorized disposal facilities (NPDES outfalls and injection wells) are operational.

All waters used to test the integrity of the gas gathering pipelines will be injected into an authorized water disposal facility in compliance with all applicable requirements.

Dust abatement will comply with all applicable WOGCC requirements. Only water suitable for livestock use would be used for dust abatement.

HYDROLOGIC ANALYSIS OF WATERSHED

Hadsell Draw and Abundance and Bountiful Tributaries are ephemeral drainages that flow mostly in response to precipitation and snowmelt. These streams are supplemented by bedrock discharge but do not maintain a quantifiable baseflow.

Peak flow for Hadsell Draw and Abundance and Bountiful Tributaries were calculated using regression equations developed by the USGS Miller (2003) and H.W. Lowham (1988). These equations relate physical and climatic characteristics of the drainages to flow characteristics of gaged streams, and provide a tool for estimating mean annual and peak flow in drainages where gaging data are not available. Due to a lack of measured flow data for these ephemeral drainages, it is difficult to make flood flow comparisons other than empirically. Flow monitoring, the establishment of permanent cross-sections and field verification of channel morphology described in **Attachment 6** will be employed to more accurately characterize peak flows in these drainages.

Calculated values for the 2-year, 5-year, 10-year, 25-year, 50-year and 100-year 24-hour storm events, as well as mean annual flow for Hadsell Draw, Abundance Tributary, and Bountiful Tributary were tabulated and are represented in **Table D-3**. The flow estimates calculated and the hydrologic and geomorphic characteristics of these drainages are provided in **Attachment 1**.

TABLE D-3 ANALYSIS OF PEAK FLOW

Drainage	Recurrence Interval (years)	Peak Discharge (cfs) 95% Confidence Intervals (low, high)
Hadsell Draw	2	100 (29, 342)
Mean Annual Flow = 0.54 cfs	5	249 (82, 759)
= 388.2 ac-ft/yr	10	395 (133, 1177)
	25	631 (209, 1907)
	50	845 (270, 2644)
	100	1088 (331, 3579)
Abundance Tributary to Hadsell Draw	2	29 (8, 100)
Mean Annual Flow = 0.09 cfs	5	79 (26, 240)
= 65.3 ac-ft/yr	10	131 (44, 390)
	25	220 (73, 664)
	50	304 (97, 951)
	100	403 (123, 1327)
Bountiful Tributary to Hadsell Draw	2	13 (4, 44)
Mean Annual Flow = 0.03 cfs	5	37 (12, 112)
= 20.0 ac-ft/yr	10	63 (21, 188)
	25	110 (36, 351)
	50	155 (49, 484)
	100	210 (64, 689)

REPRESENTATIVE ANALYSIS OF WATER QUALITY

A complete laboratory analysis of a sample from a representative gas well discharge is included in **Attachment 2**. This sample was collected from a fee well in the SE quarter of Section 9 in T18N R89W. This analysis indicates a relatively low level of total dissolved solids (TDS) (1,028 milligrams per liter [mg/L]) for discharge waters; the pH is higher than average, or slightly alkaline (8.50). The presence of sulfates (28 mg/L), chlorides (59 mg/L), and radium (0.45 picocuries per liter [pCi/L]) were minimal, while total petroleum hydrocarbons (TPH) were undetectable. Concentrations of lead at 5.5 micrograms per liter (µg/L) and zinc at 141 µg/L are relatively high and will be monitored after the water is discharged from the conditioning process discussed in the next section.

OVERVIEW AND PREDICTED RESULTS OF WATER CONDITIONING

The analysis of water samples shown in **Attachment 2** is typical of the quality of water produced by wells completed in the Mesaverde coals within the Atlantic Rim area. The water typically varies in concentrations for key constituents, as shown in **Table D-4**.

TABLE D-4 RANGE OF CONSTITUENTS IN RAW WATER

Constituent/Quality	Range of Values
Barium, µg/L	235 – 2,400
Sodium, mg/L	439 – 900
Calcium, mg/L	4 – 34
Magnesium, mg/L	5 – 18
Electrical Conductivity (EC), µmhos/cm	1,800 – 3,800
Total Dissolved Solids (TDS), mg/L	1,000 – 1,800
Sodium Adsorption Ratio (SAR), unitless	21 - 50

Notes: µg/L = micrograms per liter
mg/L = milligrams per liter
µmhos/cm = microhmos per centimeter

In general, the quality of the produced water that the Companies envision under the project meets WDEQ guidelines for livestock and wildlife watering. The Companies propose to condition the produced water to irrigation-quality water, which, when surface discharged, may enhance natural infiltration.

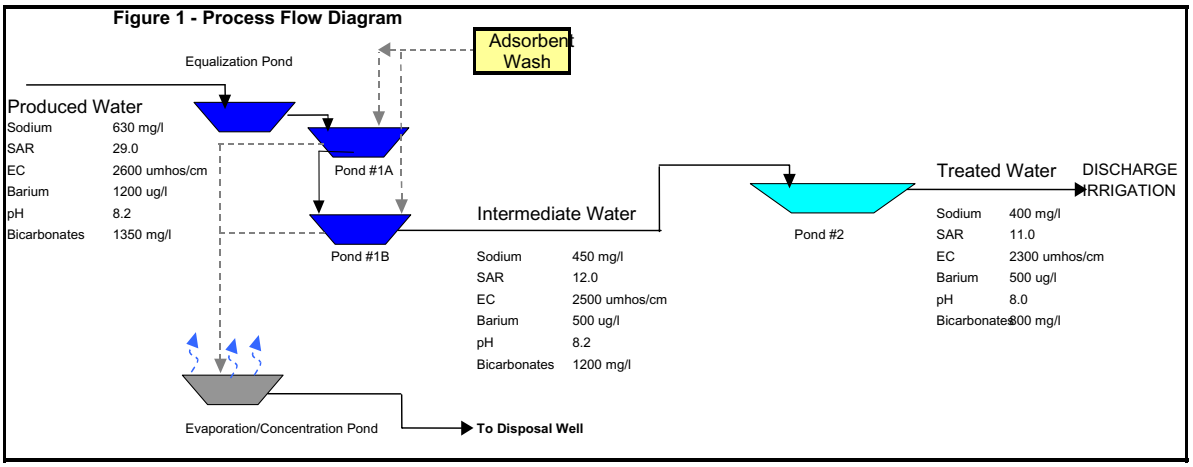
A proprietary process will be used to condition the water to irrigation quality. This water conditioning facility would be non-commercial; therefore, the ponds used for conditioning produced water will be permitted through the BLM, WSEO, or the WOGCC, as appropriate. The process is natural mineral-based and minimizes the use of mechanical equipment, does not operate under high pressure, has no potentially harmful chemical additives, and can condition the water to irrigation quality economically. Because of the potential proprietary nature of the process, its description is limited. This process will be the first full-scale application of its kind in the Atlantic Rim EIS study area and will require extra attention to minimize start-up problems and allow for scale-up of pilot tests.

Two water conditioning facilities will be constructed on fee lands in the Project Area under alternative 1. The Abundance Treatment Site will be located in the NENE of Section 21 in T20N R89W, and the Bountiful Treatment Site will be located in the SWNE of Section 29 in T20N R89W. Each site will discharge to one of the three outfalls described earlier. Under alternative 2and 3 the Bountiful Treatment Site and outfall may not be needed with the lower volume of produced water. The Companies will notify the BLM if produced water volumes require the use of the Bountiful Treatment Site and outfall under alternative 2.

The conditioning process consists of two parts. The first part uses naturally occurring materials to act as an adsorbent of sodium ions, metals, and other cations while allowing the water and anions to pass through. The second part uses aeration to reduce the concentration of bicarbonates and increase the irrigation quality of the water. This process is described in greater detail below.

A process flow diagram is shown in **Figure D-1**. The produced water is routed to an equalization pond that creates a buffer on the process for the inlet volume. From the equalization pond, water is routed to Pond #1A and on to Pond #1B, which is operated in series with Pond #1A. Pond #1A reduces the concentration of sodium and increases concentrations of calcium and magnesium in the water. Pond #1B further reduces the concentration of sodium while also reducing concentrations of anions, and particularly of bicarbonates. Throughout Ponds #1A and #1B, the concentrations of certain metals such as arsenic, radium, and barium are reduced, if they are present in the water. There will be no designated or beneficial uses of the water contained in the equalization pond or in Ponds #1A or #1B.

Figure D-1 Process Flow Diagram



The effluent from the first set of ponds is then routed to Pond #2 (refer to **Figure D-1**). In the second process, the water is allowed to aerate and oxidize bicarbonates, reducing the concentration of bicarbonate ions in the water. The reduction in bicarbonates should reduce the EC and TDS of the water from the intermediate step. At some time, the Companies may allow for enhanced aeration via mechanical processes. However, the Companies initially intend to allow a natural process to occur in Pond #2, but may add

equipment as necessary to achieve the required results. Additional equipment needed to enhance aeration of the system will be permitted through the appropriate state or federal agency and will be designed to meet the standards required for operation.

The effluent from Pond #2 will be considered irrigation-quality water with the range of characteristics as shown in **Table D-5**. The ranges shown for each characteristic or constituent of the water are independent of the other constituents listed in **Table D-5**. For example, the high values for concentrations of calcium, magnesium, and sodium do not correlate to the high value of the range of possible SAR values.

TABLE D-5 RANGE OF CHARACTERISTICS FOR CONDITIONED WATER

Constituent/Quality	Range of Values
Barium, µg/L	100 – 500
Sodium, mg/L	300 – 450
Calcium, mg/L	20 – 120
Magnesium, mg/L	20 – 40
Electrical Conductivity (EC), µmhos/cm	2,000 – 2,800
Total Dissolved Solids (TDS), mg/L	1,000 – 1,800
Sodium Adsorption Ratio (SAR), unitless	9.0 - 12

Notes: µg/L = micrograms per liter
mg/L = milligrams per liter
µmhos/cm = microhmos per centimeter

Periodically and as needed, Ponds #1A and #1B will be washed with a modifying solution to regenerate their conditioning ability. The wastewater from a pond wash will be a concentrated brine solution that will be stored in the evaporation/concentration pond. This concentrated brine will be approximately 2 to 3 percent of the inlet volume. Thus, for a conditioning site operating at 15,000 barrels per day (BPD) (439.5 gallons per minute [gpm]), approximately 300 BPD of concentrated brine will be routed to the evaporation/concentration pond. There will be no designated or beneficial uses of the water contained in this pond. Instead, water from the evaporation/concentration pond will be injected into one of two injection wells being permitted as part of the Application for Permit to Drill (APD) process.

All ponds in the process will be engineered and constructed by qualified contractors that are bonded in the State of Wyoming. The evaporation/concentration pond will be lined with a single layer of 60-mil high-density polyethylene (HDPE) to prevent any loss of fluid to shallow aquifers or surrounding soils. Ponds #1A and #1B will also be lined with a single layer of 60-mil HDPE to prevent loss of the conditioning medium. Pond #2 will be an unlined, open earthen pond. Because of the pond design and its longer retention time, higher infiltration and evapotranspiration rates through Pond #2 are anticipated. Water from Pond #2 will flow to either Outfall RR-D1 on the Bountiful Tributary or to Outfalls RR-D2 and RR-D3 on the Abundance Tributary.

The evaporation/concentration pond will be large enough to store brine solution for a number of weeks. The brine solution will be disposed of in either of two saltwater injection wells currently being permitted by the Companies. The AR Fee 21I well located in NENE of Section 21 in T20N R89W and the AR Fee 29I well located in the NWNE of Section 29 in T20N R89W will be permitted as water injection wells and will

manage the majority of the concentrated brine for disposal. At some point, the evaporation/concentration pond will be allowed to dry, and all remaining solids will be disposed of at a certified disposal facility.

The results of the initial pilot plant testing for this conditioning process are included in **Attachment 3**. This pilot testing used water samples from the Sun Dog POD gas wells, which are currently producing. The water samples collected from various points in the Sun Dog system are also produced from the Mesaverde coal seams. The characteristics of the unconditioned water are listed in each table in the row marked "RAW #1" or "RAW #2." Certain critical characteristics of the water were tracked versus retention time for the process, and the results are shown in the subsequent rows of each test below the row labeled "RAW." As shown, in both pilot tests, SAR was reduced to below 9 and EC was reduced below 2,900 µmhos/cm. Both tests used water from wells completed in the Mesaverde coals; similar tests used other produced waters of varying qualities, with comparable results.

DESCRIPTIONS OF FACILITIES

Multiple facilities will be installed or upgraded in the Hadsell Draw, Abundance, and Bountiful drainages to manage potential water discharges and naturally occurring storm events, depending on the alternative selected. These facilities include three proposed outfall structures, two proposed injection wells, an existing reservoir, two conditioning facilities, 27 proposed culverts, and five stock watering facilities. Each facility is explained below and is illustrated on Figure 2-1 of the EA (Project Map)**.**

OUTFALLS

The proposed outfall structures listed in **Table D-6** for discharge of produced water will be installed in three locations on fee lands in Hadsell Draw, under alternative 1. The locations of the outfalls were determined in consultation with the landowner. Furthermore, outfall locations were selected in accordance with the proposed NPDES permit application and the WDEQ's preference for minimizing the amount of water that would discharge to a given channel section, thereby reducing localized erosion. If the water production from the proposed wells is less than anticipated, the Companies may elect not to construct one of the outfalls in Section 21. The outfall in Bountiful Tributary may not be necessary under alternatives 2 or 3.

Outfalls will be located in stable, well-developed, low-gradient channels or as close as possible to the main stem to minimize surface erosion. Each outfall will consist of a vertical discharge pipe set inside a rubber tire stock tank surrounded by a scoria or rock riprap pad. A drain will be set in a suitable scoria or rock trench that slopes to the channel bottom to prevent discharged water from eroding the channel bank. The design of the outfall is illustrated in **Attachment 4**. Energy dissipation devices will be incorporated into the outfall structure to further dissipate discharged water and decrease the probability of erosion.

Produced water will be conditioned and then discharged through outfalls RR-D1, RR-D2, and RR-D3 to Abundance and Bountiful Tributaries, under alternative 1**.** Two outfalls will be used to help distribute and manage the effluent flows and reduce the potential for erosion in Abundance Tributary. Under alternative 2, the Bountiful outfall and treatment facility would not be constructed without BLM notification and a change to the decision record. Under alternatives 1 and 3 the Bountiful outfall and treatment facility would be constructed at the discretion of the Companies.

TABLE D-6 OUTFALL LOCATIONS AND CONTRIBUTING WELLS

Outfall	RR-D1	RR-D2	RR-D3
Location	T20N R89W Sec 29 SWNE	T20N R89W Sec 21 NENE	T20N R89W Sec 21 NENE
Contributing Wells	AR Fee 2089 SE 29	AR Federal 2089 SW 20	AR Federal 2089 SW 20
	AR Fee 2089 SW 29	AR Federal 2089 SE 20	AR Federal 2089 SE 20
	AR Fee 2089 NW 29	AR Federal 2089 NE 20	AR Federal 2089 NE 20
	AR Fee 2089 NE 29	AR Fee 2089 NE 21	AR Fee 2089 NE 21
	AR Federal 2089 NW 28	AR Fee 2089 SE 21	AR Fee 2089 SE 21
	AR Federal 2089 NE 28	AR Fee 2089 NW 21	AR Fee 2089 NW 21
		AR Fee 2089 SW 21	AR Fee 2089 SW 21
		AR State 2089 SW 16	AR State 2089 SW 16
		AR State 2089 NE 16	AR State 2089 NE 16
		AR State 2089 SE 16	AR State 2089 SE 16

WATER INJECTION WELLS

Two water injection wells, AR Fee 21I, located in the NENE of Section 21 in T20N R89W, and AR Fee 29I, located in the NWNE of Section 29 in T20N R89W, will be used for disposal of the concentrated brine solution created during the water conditioning process or for untreated waters as needed. These two injection wells will dispose of the majority of the concentrated brine solution. All water disposal plans will be permitted with the applicable State agency regulating these facilities, including but not limited to the WOGCC or WDEQ.

At each injection facility, centrifugal pumps, reciprocating pumps, filter systems, and tanks will be used to remove solids from the waste stream and to pump the waste water to pressures sufficient to allow downhole disposal of the water. The minimum capacity of each injection well is 5,000 BPD. The total produced water for the existing and proposed project before treatment would be 23,400 BPD (approximately 15,920 BPD from state and fee and 7,480 BPD from federal leases). The maximum discharge considering potential future development in the watershed would be 35,100 BPD. Of this water 2-3 % will need to be injected as a brine solution, leaving approximately 9,400 BPD available for injection of other water or 9,100 BPD for the future development scenario. Therefore, under alternative 1 the injection wells would be sufficient for water disposal from federal leases.

The injection targets for each injection well are the Hatfield, Cherokee and Deep Creek Sandstones, located approximately 5,965 to 6,335 feet below the surface. These injection wells are stratigraphically below the coal zones being explored. These sandstones are isolated above and below by competent shale barriers that would prevent initiation and propagation of fractures through overlying strata to any zones of fresh water. Maximum pressure requirements for the injection zone would be established through injectivity tests that would identify fracture pressure limits to prevent the overlying shale from being breached by fractures. Injection horizons will not be exceeded based on injectivity tests and applicable permit limits, as requested by the State of Wyoming and BLM.

The injection wells will be drilled, cased, and cemented from total depth (50 feet below the base of the Hatfield, Cherokee and/or Deep Creek Sandstone) to the surface. The injection horizon will be tested to determine its suitability for water disposal prior to any injection activities. The open-hole log and injectivity test will be provided to all necessary agencies. Also, prior to injection of the concentrated brine solution, a water analysis from the injection horizon will be obtained and provided to all necessary agencies.

RESERVOIRS

There are no existing permitted reservoirs in the Project Area, according to a recent search of the WSEO database (see **Attachment 5**). Two existing reservoirs may be affected by discharge in the Project Area, however the Espy reservoir will not receive surface discharges during low flow conditions (July – March), discharge will however will add to natural flows that may reach this reservoir during storm events during the low flow period.. These reservoirs and associated data are presented in **Table D-7** below. Mean annual flow has been estimated for each of these reservoirs and does not consider the storage effects from upstream reservoirs.

TABLE D-7 RESERVOIRS

Reservoir Information	Abundance	Espy
WY SEO Permit #	N/A	N/A
Location	NESE Sec 16, T20N, R89W	NESE Sec 3, T20N, R89W
Structural Condition	Poor	Poor
Capacity (ac-ft)	<5	5-10
Basin Area (mi^2)	1.83	N/A
Mean Annual Flow (ac-ft)	54.9	N/A
Average Maximum Discharge (gpm)	585	N/A
Crest Length (feet)	472	300
Width (feet)	449	150
Depth (feet)	5	10
Outflow Pipe	Yes	No
Spillway	Earthen	None

These reservoirs were examined during field reconnaissance and showed signs of significant deterioration or failures.

To accommodate discharge from the Red Rim wells, Abundance Reservoir will require modification and upgrade by installing a drop-inlet spillway structure (an agri-drain). This modification will enable the reservoir to better manage additional flows and to comply with newly established WSEO permitting requirements that are specific to water produced during recovery of natural gas. Abundance Reservoir will be permitted as a stock reservoir in accordance with the pertinent requirements of WSEO. In the reservoir design, the WSEO generally requires a minimum of 2 feet of freeboard, and inside embankments no steeper than 3:1 (horizontal:vertical). Furthermore, the reservoir must be equipped with a controllable low-level outlet pipe to allow for proper regulation. For stock watering purposes, the reservoir will be less than 20 acre-feet in capacity and the

dam height will be less than 20 feet. A copy of the approved WSEO permit will be provided to the BLM for their files when available.

Espy Reservoir is an on-channel reservoir located within Hadsell Draw. The Companies do not propose any modifications to this reservoir. Produced water flows are not expected to reach this reservoir (located in section 3 of T20N R89W) during low flow conditions (July – March typically, defined for analysis as the period where the channel would under natural flow conditions be dry). However, natural flows may reach this reservoir in response to large rainstorms during the low flow period, and these flows will be augmented by surface discharges. Produced water will be managed accordingly using deep well injection as necessary to ensure that flows do not reach this reservoir during low flow conditions. Deep injection will only be used if flows are making it to the reservoir during low flow conditions. If additional injection wells are needed to manage these discharges they will be added and permitted as necessary.

CONDITIONING FACILITIES

Two water conditioning facilities will be installed on fee lands in the Red Rim Project Area, under alternative 1. Under alternative 2 it is likely that the Bountiful treatment facility and outfall wouldn't be needed. The area covered by each conditioning facility is expected to be 365 feet long by 300 feet wide. Both conditioning facilities will be fenced to limit access by livestock.

It is anticipated that the conditioning ponds will be used for the length of time that the wells described in this WMP produce, plus the length of time for production of other wells added to the conditioning facility. When production of the gas wells is complete, all zeolite materials from the ponds, and the liquid and solid materials in the ponds will be disposed of in accordance with all applicable permit requirements, standards, and regulations. The Companies will seek surface owner approval and provide BLM with design drawings/layout of the Bountiful water conditioning facility. All ponds and disturbed areas will be filled, covered, and remediated per WOGCC and BLM requirements.

RESERVE PITS

Temporary reserve pits would be constructed at each drill location to contain drilling fluids and initial pressure testing. These pits would be reclaimed after well completion operations and no discharge of produced water would occur in these pits after the initial well completion operations. The Companies estimate that each reserve pit would be open for 2 to 8 weeks to allow pit fluids to evaporate.

The reserve pits would be constructed in cut rather than fill materials. Fill material would be compacted and stabilized, as needed. The subsoil material of the pits would be inspected to assess stability and permeability and to evaluate whether reinforcement or lining would be required. If lining is required, the reserve pit would be lined with reinforced synthetic liner at least 12 mils thick and with a bursting strength of 175 by 175 pounds per inch (American Society for Testing and Materials [ASTM] Standard D

75179). Use of closed or semi-closed drilling systems would be considered in situations where a liner may be required.

Two feet of freeboard would be maintained in all reserve pits to ensure they are not in danger of overflowing. Drilling operations would be shut down if leakage is found outside the pit until the problem is corrected.

CULVERTS

The main access road and existing improved and unimproved roadways within the Project Area cross channels at existing culvert crossings. Some proposed road improvements will cross drainages and may require installation of culverts. The proposed roadway system uses existing improved roads and proposed locations that avoid channels where possible to minimize effects. If necessary, culverts will be a minimum of 18 inches in diameter and will be sized to adequately manage existing and potential flows. The proposed road culverts (27 total) are illustrated in Figure 2-1 of the EA (Project Map)**.** These crossings will be monitored for adequate capacity and potential buildup of ice during the winter. Methods for culvert installation are described in the MSUP and in Chapter 2 of the Red Rim EA.

STOCK WATERING FACILITIES

Five stock tanks will be installed in the Project Area, as shown in Figure 2-1 of the EA (Project Map)**.** A stock tank will be located at each of the three proposed outfalls, and will be designed to overflow and discharge to surface drainages. The other two stock tanks will be installed using a float valve to manage flows to the tanks and prevent discharge to the surface. All of these stock tanks will provide a source of water to livestock and resident wildlife.

EXISTING AND POTENTIAL EROSION

Surface disturbance associated with road construction, drilling, and installing pipelines or utilities could increase the potential for erosion and are discussed in the main body of the EA. The Companies would implement the mitigation measures described in Chapter 2 of the EA to control wind and water erosion at disturbed sites so that interim drilling and development in the Project Area would not affect surface drainages.

Increased surface water runoff and off-site sedimentation caused by soil disturbance, impairment to surface water quality, and changes in stream channel morphology may be caused by construction of roads, drill locations, and pipeline crossings. Construction would occur over a relatively short period, however. Impacts from construction would likely be greatest in the short term and would decrease over time as a result of stabilization, reclamation, and revegetation. Construction disturbance would not be uniformly distributed across the Project Area, but instead would be concentrated near the drill locations and access or utility routes.

The receiving channels of Hadsell Draw, Abundance Tributary, and Bountiful Tributary were inspected for erosional features and potential degradation. No significant erosion or potential erosion features were found. Although there are small erosional features that may be exacerbated by surface discharge, these will be evaluated during monitoring, as described in the Monitoring and Mitigation section. Hadsell Draw exhibits many pothole-type features that will fill and be submersed as the influence of discharge water progresses downstream. These potholes do not pose any significant potential for erosion and will be monitored during scheduled inspections and after major storm events. All channels will be monitored after discharges from federal wells as per BLM guidelines.

As described previously, outfalls will be located in stable, well-developed, low-gradient channels or as close as possible to the main stem to minimize surface erosion. Each outfall will consist of a vertical discharge pipe set inside a rubber tire stock tank surrounded by a scoria or rock riprap pad. A drain will be set in a suitable scoria or rock trench that slopes to the channel bottom to prevent discharged water from eroding the channel bank. Energy dissipation devices will be incorporated into the outfall structure to further dissipate discharged water and decrease the probability of erosion.

DOWNSTREAM IMPACTS

Continuous discharge to previously ephemeral drainages will cause native vegetation to undergo changes that could affect the stability of existing impoundments and natural channels. As these changes occur, native dryland grass communities will be most likely be replaced with wetland species that are more tolerant and characteristic of perennial flows. Bank stability may also improve with the transition to wetland species. Some wetland species are less desirable to domestic livestock and wildlife, however others may be preferentially grazed during normal operations. During this transition period, natural channels may appear to support more limited vegetative cover for a short period while wetland species become established. Vegetation will be monitored as described in the Monitoring and Mitigation section.

Surface drainages may be affected by increased flows from discharges of produced water where channels are not stable or armored. All channels that receive discharged water will be monitored for degradation, as described in the Monitoring and Mitigation section. Furthermore, the Companies will work with downstream landowners to mitigate potential problems with access by installing additional or modifying existing channel crossings.

Downstream impacts should be minimal since the discharge should not reach the reservoir on Handsell draw below the condfluence with Abundance tributary (T20N R89W, Section 3) during low flow conditions. Discharges will add to the salt loading of the channel beds in the Handsell draw system. Salt loading will be monitored as described in the Monitoring and Mitigation section at the soil sample locations and actions taken as described.

MONITORING AND MITIGATION

Aquifers and groundwater quality are not anticipated to be affected by the project provided the mitigation measures that are described in Chapter 2 of the EA are implemented. A groundwater monitoring program is being established for the Atlantic Rim EIS study area, including one monitoring well located in the Red Rim Pod. Water from the Cherokee or Deep Creek Sandstones will be analyzed and the results provided to all necessary regulatory agencies before injection begins. It is anticipated that the produced water that would be injected would be of equal or higher quality in regard to class of use as defined by WDEQ Ground Water Division regulations.

Testing of CBNG resources likely would lower the hydraulic head in the affected coal seam aquifer. (The reduction of hydraulic head in an aquifer also is referred to as drawdown.) Relative to the available drawdown within the aquifer, the effect on the coal aquifer during the interim drilling project is expected to be small. BLM has requested that three to six groundwater monitoring wells be installed within the Atlantic Rim EIS study area during the interim drilling project. Two of these wells have been drilled and the third will be located at this pod. The effects of interim drilling and development on the coal aquifer, including drawdown, will be monitored by these wells and they will provide data for a groundwater model to look at potential impacts from alternatives in the EIS. Monitoring wells do not count toward the limit of 24 proposed wells in a POD under the Interim Drilling Policy.

The water level also may be lowered or drawn down in existing wells within the 1/2-mile radius of individual exploratory wells completed in the Mesaverde aquifer. The potential yield from the nearby water wells may be affected by removal of groundwater. Other wells completed in the coal seams could be affected by the project; however, no other wells permitted by the WSEO are known to occur within 1 mile of the Project Area. Potential effects on water wells would be minimized by a water well agreement, as described in the Master Surface Use Program (MSUP) (**Appendix B** of the EA) and the other mitigation measures described in Chapter 2 of the EA.

The Companies will initiate a monitoring plan for the receiving channels within the Project Area. The Companies will establish a set of baseline data of the physical and biological condition of the receiving channels, where applicable, and perform scheduled monitoring to assess the impact from flows of produced water. The Companies in coordination with the BLM will employ internal company resources as well as qualified third-party contractors to assist in acquiring baseline data and perform the monitoring. The monitoring and mitigation plan is described in detail below. The monitoring schedule is included in **Attachment 6**.

A. Baseline Data Acquisition

The Companies will collect data to evaluate the current conditions of soil, vegetation, and bank stability in the proposed receiving channels for the Red Rim wells. These data will form the baseline for initial channel conditions, and serve as a checkpoint for future monitoring to indicate both positive and negative changes in the physical and biological

condition of the receiving channels. A baseline data report including all data collected will be provided to the BLM after this effort is completed. Refer to **Attachment 6** for information on proposed monitoring points and timing.

1. *Soils* – The Companies will collect soil samples for laboratory analysis from areas that may be affected by proposed flow of water. Soil samples will be collected from the upper reaches of the Abundance and Bountiful Tributaries, and Hadsell Draw. Each location where a soil sample is collected will be recorded via global positioning system (GPS) so that samples can be collected at the same locations in the future during periodic monitoring. Proposed soil sample locations are shown on Figure 2-1 of the EA (Project Map). All soil samples will be analyzed, at a minimum, for pH, EC, SAR, texture, organic matter, and lime content. A subset of the surface soils, at the Companies' discretion, will be analyzed for clay mineralogy, boron, selenium, and molybdenum.

   The Companies will walk the receiving channels and photo-document any natural seeps or conditions that have not experienced flow to date and that warrant further investigation. Each site will be recorded via GPS, and photos of the sites will be taken. These conditions may be, but are not limited to, naturally alkaline soil conditions, areas of limited vegetation growth, or soil anomalies.

2. *Vegetation* – The Companies will record vegetation present at each soil sample location discussed above. Vegetation species, type, and abundance will be recorded at each location. The Companies will also establish photo-monitoring points and use digital photography to document initial conditions of vegetation before flow of water commences. The Companies will set up photo-monitoring points along drainages where future discharges will occur and will take photographs before discharge begins. All photo-monitoring points will be recorded via GPS for continuous monitoring once discharge begins. These photos will document the initial density and quality of the vegetation in the receiving channels before flow of water begins.

3. *Channel Morphology* – The Companies will walk the proposed receiving drainages to photo-document and map any areas of possible instability in the channel or bank. The Companies will also install three flow-monitoring cross sections within the receiving channels to measure instantaneous flow of water downstream of the discharge points. These cross sections will be located on fee lands within Abundance and Bountiful Tributaries, and in Hadsell Draw downstream of the confluence with the two tributaries, as shown on Figure 2-1 of the EA (Project Map). The cross sections for flow monitoring will be established before water is expected to reach the drainages. Data collected at each cross section could be used to assess natural processes such as infiltration, and evapotranspiration, and allow comparison of how these processes are altered by continuous discharge of produced water. Furthermore, prior to

surface discharge, BLM may elect to install permanent flow measurement capabilities in Hadsell Draw.

B. Periodic Monitoring

The Companies will undertake an aggressive program to monitor many physical and biological parameters within the Red Rim Project Area to facilitate any necessary remedial actions. Data collected during periodic monitoring will be compared against initial baseline data, trended for statistical analysis, or compared with general academic or scientific studies. Summary reports including all data collected will be provided to the BLM annually. These comparisons will support evaluation of the effects of produced water on physical and biological changes that may be occurring in discharge drainages. Refer to **Attachment 6** for information on proposed monitor points and timing.

1. *Water Quality* – After this WMP for the Red Rim POD and associated NPDES permit are approved by the proper agencies and the Companies begin discharging water from the Red Rim wells, the Companies will collect water samples from various points associated with the project for chemical analysis. The Companies propose to sample water at the points listed below.

    - All outfalls listed in **Table D-6**, assuming the outfall is active at the time of sampling.
    - Any points of compliance (POCs) as established with WDEQ NPDES permit, if applicable.
    - Hadsell Draw, at the confluence with Abundance Tributary, if flow reaches this point.

    Initially, samples at these locations will be collected monthly for a period of 6 months after water begins to flow from the outfalls listed in **Table D-6**. After 6 months, the Companies will collect these samples at a frequency of not less than once every 3 months. Discharge or flow will be estimated when samples are taken from natural channels.

    Each sample will be analyzed, at a minimum, for the constituents in **Table D-8**.

TABLE D-8 SAMPLE CONSTITUENT ANALYSIS

Total Petroleum Hydrocarbons	Dissolved Manganese
pH	Total Alkalinity
Specific Conductance	Calcium
Dissolved Iron	Magnesium
Total Barium	Sodium
Chlorides	Potassium
Sulfates	Bicarbonate
Total Arsenic	Fluoride
SAR	

2. *Produced Water-Related Flow* – Continuous flow rates will be recorded for each gas well after startup. In addition, flow meters or weir plates will be installed at outfalls to monitor the amount of water discharged into the tributaries of Hadsell Draw.

3. *Soils* – The Companies will collect soil samples from the points sampled and by the methods describe under the baseline data acquisition section. Samples will initially be analyzed annually for the first 2 years of the project, beginning when flow starts from the discharge points listed in **Table D-6**. After 2 years, soil samples will be collected at a minimum frequency of once every 2 years, with additional soil samples to be collected at the discretion of the Companies. Results for these soil samples will be used for comparison with baseline data to investigate the effect of produced water on soils. Refer to Figure 2-1 of the EA (Project Map) for proposed soil sample locations.

4. *Vegetation* – The Companies will use photo-documentation at the established photo-monitoring points along the receiving channels to record the growth and vigor of riparian species or zonation of other species. Vegetation species, type, and abundance will be recorded at the soil sampling locations. Initially, photos will be taken annually during the middle of each growing season. If the Companies determine that photo-documentation indicates that growth and vigor of riparian species is stable, photo-documentation will be conducted every other year.

   The Companies will also walk the channels to record the vegetation present. This vegetation inventory will occur once per year, during the period between June and September, and will be conducted by qualified third-party experts or contractors. The Companies will use the photo-documentation and inventory to track changes in vegetation along the receiving channels and in the banks and alluvial swales immediately surrounding the channels.

5. *Channel Morphology* – The Companies will initiate periodic monitoring of the receiving channels to identify any negative impact on bank stability associated with discharge of produced water. Company personnel will visually inspect each discharge point on a monthly basis for the first year of flow from the discharge points listed in **Table D-6** and every 6 months in all subsequent years while discharge continues. Inspectors will note the condition of the outfall site, check for evidence of erosion downstream of any structures constructed for energy dissipation and will schedule any remedial work required at the outfalls.

   Abundance Reservoir will be inspected quarterly and after a 25-year or larger storm event for the first year of operation after discharge begins from the points listed in **Table D-6**. Field personnel will check the reservoir on a bi-annual basis and after a 25-year or larger storm event

during each subsequent year. Inspectors will note the condition of the outlet pipe and spillway, check for evidence of erosion or deterioration, and schedule any remedial work required at the reservoir.

Company personnel and a qualified third-party contractor will walk the receiving channels associated with this project once each 6 months during the first 2 years after flow begins from the points located in **Table D-6**. Thereafter, Company personnel or a qualified third-party contractor will walk the receiving channels once per year and after any 25-year or larger storm events. Inspectors will note the condition of the channels, channel banks, and alluvial areas, check for evidence of erosion or instability, and schedule any remedial work required.

6. *Groundwater Monitoring Wells* – BLM has requested that three to six groundwater monitoring wells be installed within the Atlantic Rim EIS study area during the interim drilling project. One of these wells will be located in the Red Rim Project Area. The effects of interim drilling and development on the coal aquifer, including drawdown, will be monitored by these wells.

C. Data Distribution

1. Baseline Data – The Companies will deliver baseline data that have been collected on soil, vegetation, and channel morphology to the BLM within 90 days after the data are received. These data will include but not be limited to the following:

- Digital photos from photo-documentation
- Laboratory analysis of soil samples
- Maps showing soil and water sample locations
- Laboratory analysis for water samples
- Produced water flow
- Vegetation inventories
- Channel and Bank stability issue inventories

2. Periodic Monitoring – The Companies will deliver data associated with the periodic monitoring program, as outlined above, to the BLM within 90 days after the data are received. These data will include but not be limited to the following:

- Digital photos from photo-documentation points
- Laboratory analysis of soil samples
- Maps showing soil and water sample locations and areas of interest
- Results from channel walks noting vertical or lateral adjustments.
- Laboratory analysis for water samples
- Produced water flow

3. *Additional Reporting* – The Companies will also file with the BLM RFO any scope of work and results of studies on water discharge conducted by the Companies in conjunction with other regulatory, government, or academic agencies. These other bodies may include the University of Wyoming, the U.S. Environmental Protection Agency (EPA), WDEQ, Natural Resource Conservation Service (NRCS), U.S. Geologic Survey (USGS), or local conservation districts. The scope of work and results of these studies will be filed with BLM within 90 days after the Companies receive the documents. Under alternative 2, if the Bountiful treatment facility and outfall are needed the Companies will notify the BLM at least 3 months in advance.

D. Mitigation Plan

1. *Soils* – The Companies' periodic monitoring of soil characteristics will be examined and evaluated for patterns or areas of concern that are not caused by traditional seasonal variation and significant storm events. Should the evaluations identify discharge as the source of accelerated channel erosion, the Companies will undertake remedial action for the soils, provided that the condition was not identified in the baseline data as previously existing. Mitigation techniques may include:

   - Revegetate with saline tolerant species
   - Treat soil
   - Promote natural leaching after discharge has ended
   - Remove saline or sodic soils

   Before any remedial techniques are applied, the Companies will consult with BLM and other pertinent organizations to develop a mitigation strategy. Remediation methods may require approval of WDEQ or other regulatory agencies. Any necessary approvals will be obtained before remediation begins.

2. *Vegetation* – Vegetation species within the immediate area of the stream channels are likely to change as a result of the presence of continuous water flow. Given this change, the Companies will undertake remedial action if range conditions immediately adjacent to the zone of influence experience a detrimental effect from the produced water. The Companies will rely on the baseline information and periodic monitoring (photo-documentation and vegetative inventories) to identify potential changes in vegetation outside the zone of influence. The zone of influence is defined as areas within the drainage where discharged water and soil interact.

   If a third-party expert in biology, in conjunction with the Companies, or a Range Specialist with the BLM concludes that a detrimental effect to vegetation is occurring outside the zone of influence, the Companies will undertake investigations in conjunction with BLM to identify the reasons.

Possible reasons for changes to vegetative communities outside the zone of influence could include, but would not be limited to:

- Changes in livestock stocking rates;
- Changes in grazing patterns (due to water availability);
- Changes in climate – short term or long term;
- Range fires

Mitigation measures for discharge-related effects might include:

- Changes in grazing management such as time and use or fencing
- Enhanced propagation of native riparian species
- Revegetation with saline-tolerant species
- Removal of saline soils

Before any remedial techniques are applied, the Companies will consult with BLM and other pertinent organizations to develop a mitigation strategy. Remediation methods may require approval of WDEQ or other regulatory agencies. Any necessary approvals will be obtained before remediation begins.

The monitoring program will also obtain data on a frequent basis that will evaluate the health of vegetation within the zone of influence. In addition to water quality concerns, health of the riparian zone depends on the volume of flow from produced water. As development matures, flows will decrease and riparian species will be replaced by species associated with upland dry soils. If a third-party expert in biology selected by the Companies or a BLM biologist concludes that a detrimental effect to riparian vegetation is occurring within the zone of influence, the Companies will undertake investigations in conjunction with BLM to identify the reasons. This expert would work in conjunction with the Companies, and detrimental effects would be other than any caused by reductions in flow. The Companies will undertake remedial action if it is determined that riparian species within the zone of influence experience a detrimental effect from the produced water so that stability of the channel is threatened.

Evaluation and mitigation of changes to vegetation within the zone of influence will include the same considerations listed above for changes to vegetation outside the zone of influence.

3. *Channel Morphology* – If, through evaluations, it becomes apparent that undue bank erosion or vertical or lateral channel adjustments can be attributed to discharges, the Companies will undertake immediate remedial actions. These actions may include, but will not be limited to:

- Channel stabilization including armoring or other low impact methods.

- ∉ Redirection of flows at the outfalls to reduce flow in the areas of concerns
- ∉ Installation of stabilization structures (Plans will be submitted to the BLM for review).
- ∉ Re-sloping, matting, and planting or seeding
- ∉ Installation of flow piping to bypass surface flow along areas of concern

4. Future Sources of Water – As the project nears the end of its expected operating life, the Companies will work with local landowners, BLM, and other affected parties to establish sources of water for livestock. Establishment of these sources of water may include, but will not be limited to, the following: transfer title and operation of water producing wells to private landowners; drill additional shallow groundwater wells; and place water troughs in appropriate locations. The Companies will work in good faith with local landowners and affected agencies on the financial and operational division of continuing these management practices.

E. Cooperation

The Companies will work cooperatively to assess the impact of produced water on biologic parameters. This assessment will occur in conjunction with organizations such as BLM, WDEQ Water Quality Division, WDEQ Air Quality Division, NRCS, USGS, University of Wyoming, EPA, U.S. Fish and Wildlife Service, Coalbed Methane Coordination Coalition, Joint Powers Board, Local Conservation Districts, and many other legitimate agencies and groups. The Companies will seek to provide assistance or site access to these agencies when appropriate for legitimate studies or monitoring of the biologic systems that surround the receiving channels associated with this project. The Companies, however, reserve all rights granted to it as a landowner and leaseholder in Carbon and Sweetwater County, Wyoming.

F. Summary

The Companies will initiate an aggressive monitoring plan of the receiving channels of the Project Area. The Companies will begin the monitoring plan by establishing a set of baseline data of the physical and biological condition of the receiving channels, where applicable. In addition, they will continue scheduled monitoring to assess the impact of water flows on these conditions. The Companies will employ internal company resources as well as reputable third-party contractors to assist in acquiring the baseline data and the monitoring plan. The monitoring plan includes the following details:

- ∉ Baseline Data Acquisition – Acquisition of necessary data to establish the current conditions of soils, vegetation, and channel morphology. Refer to **Attachment 6** for information on the proposed monitor points and timing.
- ∉ Periodic Monitoring – Continued monitoring of physical and biological conditions associated with discharge of produced water into receiving channels on land monitored by BLM, including water quality, soils, vegetation, and channel morphology. Refer to **Attachment 6** for information on proposed monitor points and timing.

- Data Distribution – Distribution of all relevant data associated with the monitoring plan outlined to the BLM in a timely and efficient manner.
- Mitigation – Measures that include trigger points and anticipated actions of the Companies to mitigate any detrimental effects associated with flow of produced water.
- Cooperation –The Companies will cooperate with relevant agencies to continue to study the effects of discharge.

ATTACHMENT 1 –HYDROLOGIC ANALYSIS OF WATERSHED

Hydrologic Watershed Field Analysis Summary Sheet

POD Name: Red Rim

Watershed Involved: Hadsell Draw

Watershed Area (Miles^2)	27.0
Average Watershed Slope (ft/mi)	348.4
Geographic Factor	0.8
Average Annual Precipitation (inches)	9.2

Existing Channel Information:

Average Bank Full Width (feet)	12
Average Channel Slope (feet/foot)	0.07
Average Channel Width (feet)	10
Average Channel Depth (feet)	2

General Channel Condition:

Channel condition is good. Main stem and tributaries are well defined and stable. No apparent head cuts.

Channel Vegetative Cover / Dominant Species:

The mainstem and tributaries of possess well vegetated channels primarily composed of a mixture of Sagebrush and Native grasses.

Mean Annual Flow (cfs)	0.54
Mean Annual Flow (Ac-ft/year)	388.2

Peak Flow Analysis:

Recurrence Interval (Years)	**Probability That Value will be Exceeded (Percent)**	**Peak Flow (cfs/Miles^2)**	**Complete Basin Peak Flow (cfs)** Lowham (1988)
2	0.5	4.4	117.5
5	0.2	10.1	272.6
10	0.1	15.6	420.7
25	0.04	24.6	665.4
50	0.02	32.6	880.4
100	0.01	42.1	1136.1

Hydrologic Watershed Field Analysis Summary Sheet

POD Name: Red Rim

Watershed Involved: Abundance Tributary to Hadsell Draw

Watershed Area (Miles^2)	3.6
Average Watershed Slope (ft/mi)	294.0
Geographic Factor	0.8
Average Annual Precipitation (inches)	9.2

Existing Channel Information:

Average Bank Full Width (feet)	15
Average Channel Slope (feet/foot)	0.06
Average Channel Width (feet)	N/A
Average Channel Depth (feet)	N/A

General Channel Condition:

Channel condition is good. Main stem and tributaries are well defined and stable. No apparent head cuts.

Channel Vegetative Cover / Dominant Species:

The mainstem and tributaries of possess well vegetated channels primarily composed of a mixture of Sagebrush and Native grasses.

Mean Annual Flow (cfs)	0.09
Mean Annual Flow (Ac-ft/year)	65.3

Peak Flow Analysis:

Recurrence Interval (Years)	Probability That Value will be Exceeded (Percent)	Peak Flow (cfs/Miles^2)	Complete Basin Peak Flow (cfs) Lowham (1988)
2	0.5	11.7	41.5
5	0.2	28.5	101.6
10	0.1	44.8	159.5
25	0.04	73.4	261.3
50	0.02	98.9	352.0
100	0.01	129.8	462.2

Hydrologic Watershed Field Analysis Summary Sheet

POD Name: Red Rim

Watershed Involved: Bountiful Tributary to Hadsell Draw

Watershed Area (Miles^2)	0.93
Average Watershed Slope (ft/mi)	473.2
Geographic Factor	0.8
Average Annual Precipitation (inches)	9.2

Existing Channel Information:

Average Bank Full Width (feet)	15
Average Channel Slope (feet/foot)	0.09
Average Channel Width (feet)	N/A
Average Channel Depth (feet)	N/A

General Channel Condition:

Channel condition is good. Main stem and tributaries are well defined and stable. No apparent head cuts.

Channel Vegetative Cover / Dominant Species:

The mainstem and tributaries of possess well vegetated channels primarily composed of a mixture of Sagebrush and Native grasses.

Mean Annual Flow (cfs)	0.03
Mean Annual Flow (Ac-ft/year)	20.0

Peak Flow Analysis:

Recurrence Interval (Years)	**Probability That Value will be Exceeded (Percent)**	**Peak Flow (cfs/Miles^2)**	**Complete Basin Peak Flow (cfs)** Lowham (1988)
2	0.5	20.8	19.3
5	0.2	52.9	49.2
10	0.1	84.1	78.2
25	0.04	141.5	131.6
50	0.02	193.0	179.5
100	0.01	256.8	238.8

ATTACHMENT 2 – WATER QUALITY ANALYSIS

Client: **PETROLEUM DEVELOPMENT CORP.**
Sample ID: **AR Fee 1890 SE 9** Date Sampled: 07/19/01
Project ID: **Atlantic Rim POD 4** Date Received: 07/20/01
Laboratory ID: *P010657* Date Reported: 08/10/01

ANALYTE	RESULT	DETECTION LIMIT	METHOD	DATE ANALYZED
Total Dissolved Solids	**1028**	*5 mg/L*	EPA 160.1	*07/24/01*
pH	**8.5**	*0.1 s.u.*	EPA 150.1	*07/28/01*
Bicarbonate	**994**	*1 mg/L*	EPA 310.1	*07/28/01*
Sulfate	**28**	*5 mg/L*	EPA 300.0	*07/28/01*
Fluoride	**2**	*0.1 mg/L*	EPA 300.0	*07/28/01*
Chloride	**59**	*5 mg/L*	EPA 300.0	*07/28/01*
Specific Conductance	**1770**	*5 µmho/cm*	EPA 120.1	*07/25/01*
Radium^{226}	**0.457 ± 0.235**	*0.2 pCi/L*	EPA 903.0	*07/31/01*
Total Petroleum Hydrocarbons	**< 1**	*1 mg/L*	EPA 1664	*08/05/01*
Aluminum	**< 50**	*50 µg/L*	EPA 200.8	*08/08/01*
Total Antimony	**< 5**	*5 µg/L*	EPA 200.8	*08/08/01*
Total Arsenic	**7.3**	*0.5 µg/L*	EPA 200.8	*08/08/01*
Total Barium	**235**	*100 µg/L*	EPA 200.8	*08/08/01*
Total Beryllium	**< 0.03**	*0.03 µg/L*	EPA 200.8	*08/08/01*
Boron	**0.4**	*0.1 mg/L*	EPA 200.8	*08/08/01*
Cadmium	**< 0.1**	*0.1 µg/L*	EPA 200.8	*08/08/01*
Chromium	**3**	*1 µg/L*	EPA 200.8	*08/08/01*
Copper	**6**	*1 µg/L*	EPA 200.8	*08/08/01*
Cyanide (Total)	**< 5**	*5 µg/L*	EPA 335.2/3	*08/01/01*
Dissolved Iron	**< 30**	*30 µg/L*	EPA 236.2	*08/06/01*
Total Iron	**1325**	*30 µg/L*	EPA 236.2	*08/06/01*
Dissolved Manganese	**35**	*10 µg/L*	EPA 243.2	*08/06/01*
Total Manganese	**53**	*10 µg/L*	EPA 243.2	*08/06/01*
Nickel	**11**	*10 µg/L*	EPA 200.8	*08/08/01*
Lead	**5.5**	*2 µg/L*	EPA 200.8	*08/08/01*
Mercury	**< 0.1**	*0.1 µg/L*	EPA 245.1	*08/07/01*
Phenol	**< 50**	*50 µg/L*	EPA 420.1/2	*08/10/01*
Selenium	**< 5**	*5 µg/L*	EPA 200.8	*08/08/01*
Silver	**< 3**	*3 µg/L*	EPA 200.8	*08/08/01*
Total Thallium	**< 10**	*10 µg/L*	EPA 200.8	*08/08/01*
Zinc	**141**	*10 µg/L*	EPA 200.8	*08/08/01*
Total Hardness	**33**	*10 mg $CaCO_3$/L*	SM 2340 B.	*07/31/01*
Sodium	**19.1**	*0.1 meq/L*	EPA 273.1	*07/31/01*
Magnesium	**0.4**	*0.1 meq/L*	EPA 242.1	*07/31/01*
Calcium	**0.2**	*0.1 meq/L*	EPA 215.1	*07/31/01*
Sodium Adsorption Ratio	**33.0**			*07/31/01*

Comments: *All analyses completed within EPA established holding times.*
References: *Methods for Chemical Analysis of Water and Wastes, EPA/600/4-79-020, 1983*
Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 19th Ed., 1995

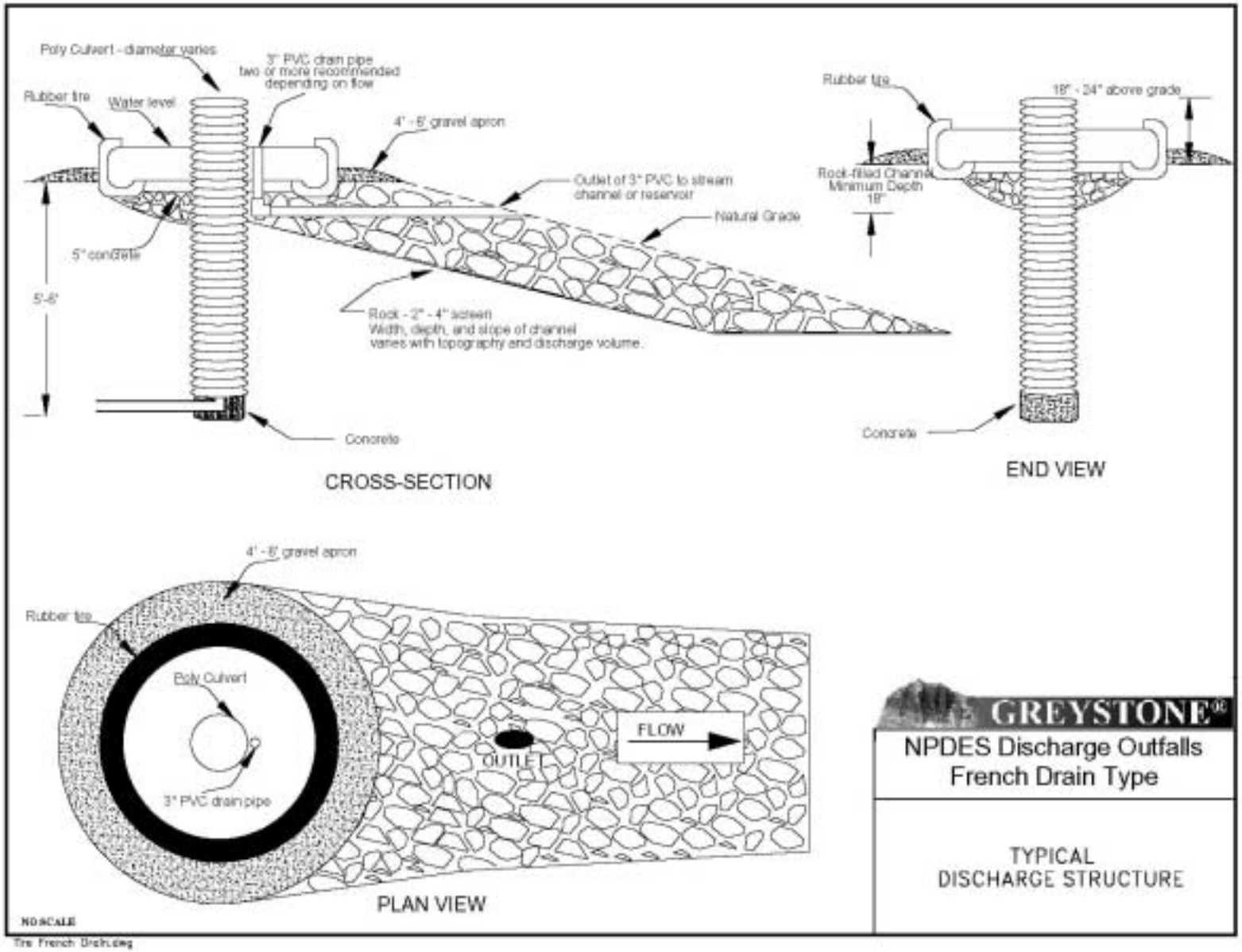
ATTACHMENT 3 – BENCH TEST RESULTS FOR WATER CONDITIONING

SUMMARY OF RESULTS FOR BENCH TEST OF WATER CONDITIONING

Prepared for. Anadarko Petroleum Corporation

Sample	Ca	Ca	Mg	Mg	Na	Na	SAR	EC	HCO3	Ba	Fe	
	mg/L	*meq/l*	*mg/L*	*meq/l*	*mg/L*	*meq/l*		*mmhos*	*mg/L*	*µg/L*	*mg/L*	
Raw #1	13.3	0.67	4.9	0.41	912	39.7	54.3	3840	1854	1180	ND	
R1	30.2	1.51	136.5	11.38	699.2	30.4	12.16	4250	1177	230	ND	
R2	12.6	0.63	128.9	10.74	544.1	23.66	9.9	4333	1678	173	ND	
R3	12.2	0.61	118.8	9.9	532.1	23.13	10.06	3980	1880	136	ND	
S1	101.5	5.08	43.6	3.63	433	18.83	8.96	2610	777	103	ND	w/o aeration
S2	121.4	6.07	33.6	2.82	439.4	19.1	9.09	2590	679	125	ND	w/o aeration
S3	98.7	4.94	12.8	1.07	489.8	21.3	12.3	2880	603	156	ND	w/o aeration
Raw#2	21.2	1.06	6.1	0.51	689	38.65	43.5	3910	1899	1070	ND	
R'1	18.8	0.94	122.2	10.18	619	26.91	11.4	4545	1808	221	ND	
R'2	23.6	1.18	143.3	11.94	623.4	27.1	10.58	4214	1618	216	ND	
R'3	12.9	0.65	116.6	9.72	518.2	22.53	9.88	3988	1701	179	ND	
S'1	191.6	9.56	23.4	1.95	499.6	21.72	9.05	2890	998	143	ND	w/o aeration
S'2	145.3	7.27	43.3	3.61	438.7	19.07	8.18	3145	897	142	ND	w/o aeration
S'3	145.9	7.3	42.3	3.53	444.9	19.34	8.3	3266	766	156	ND	w/o aeration
S'4	122.6	6.13	33.6	2.8	432.8	18.82	8.92	2988	787	124	ND	w/o aeration
R'4	32.1	1.61	101.1	8.43	528.8	22.99	10.27	3544	1455	166	ND	
S'4	108.7	5.44	22.1	1.84	466.5	20.28	10.67	2786	764	123	ND	w/o aeration
Avg.S3 & S4	103.7	5.185	17.45	1.45417	478.15	20.7891	11.49	2834	683.5	139.5	ND	

ATTACHMENT 4 – OUTFALL DESIGN



fire French Ditch.dwg

ATTACHMENT 5 – WSEO SURFACE WATER SEARCH

Wyoming State Engineer's Office Surface Water Search

Cert. Rec.	Pfx	Permit No.	Sfx	Tns	Rng	Sec	Qtr	Qtr/ Qtr	Acres	Status	SupTy	Ov Status	Uses	Facility Name	Applicant	Source	Priority	Una Amt	Una Unit	rCap Tot
		P1148R		20	89	16	8	SENW		PU	ORI	ADJ	STO, IRR	Cullin Reservoir	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	38.15	ACFT	38.15
		P1148R		20	89	16	8	SENW		PUO	ORI	ADJ	STO, IRR	Cullin Reservoir	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	38.15	ACFT	38.15
		P1148R		20	89	16	9	NESW		PU	ORI	ADJ	STO, IRR	Cullin Reservoir	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	38.15	ACFT	38.15
		P8076D		20	89	9	12	SESW	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	9	15	SWSE	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	2	NWNE	12	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	3	SWNE	8	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	5	NENW	35	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	6	NWNW	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	7	SWNW	30	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	8	SENW	20	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	8	SENW		PUD	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
		P8076D		20	89	16	10	NWSW	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	JOHN J. CULLIN	SOLON DRAW	11/07/ 1907	0	CFS	
C34/258A	P	1148	R	20	89	16	8	SENW		PU	ORI	ADJ	IRR, STO	Cullin Reservoir	John J. Cullen	Solon Draw	11/07/ 1907			
C34/258A	P	1148	R	20	89	16	8	SENW		PUO	ORI	ADJ	IRR, STO	Cullin Reservoir	John J. Cullen	Solon Draw	11/07/ 1907			
C34/258A	P	1148	R	20	89	16	9	NESW		PU	ORI	ADJ	IRR, STO	Cullin Reservoir	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	2	NWNE	12	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	3	SWNE	8	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	5	NENW	35	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	6	NWNW	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	7	SWNW	30	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	8	SENW	20	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	8	SENW		PUD	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	16	10	NWSW	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	9	12	SESW	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			
C34/259A	P	8076	D	20	89	9	15	SWSE	5	ADJ	SEC	ADJ	IRR	Cullin Ditch	John J. Cullen	Solon Draw	11/07/ 1907			

ATTACHMENT 6 – INITIAL PERIODIC MONITORING SCHEDULE

Monitoring Category Monitor Point *Monitor Action*	**Initial Monitoring** **Baseline Data**	**Year 1**											
		Quarter 1			**Quarter 2**			**Quarter 3**			**Quarter 4**		
		Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Soil													
Soil Sample	Pre-Flow<==>						<==>						
Channel Inspection													
Photo Document	Pre-Flow <==>			<==>			<==>			<==>			<==>
Map Points	Pre-Flow <==>									<==>			
Vegetation													
Record vegetation at													
Sample sites	Pre-Flow <==>												
Photo Monitoring													
Photo Document	Pre-Flow <==>						<==>			<==>			
Channel Topography													
Channel Inspection													
Outfall Inspection		<==>	<==>	<==>	<==>	<==>	<==>	<==>	<==>	<==>	<==>	<==>	<==>
Reservoir Inspection				<==>			<==>			<==>			<==>
Photo Document	Pre-Flow <==>						<==>						<==>
Map Points	Pre-Flow <==>						<==>						<==>
Water Quality													
Sample Analysis at		<==>	<==>	<==>	<==>	<==>	<==>			<==>			<==>
listed points													

Monitoring Category Monitor Point *Monitor Action*	**Initial Monitoring** **Baseline Data**	**Year 2**											
		Quarter 1			**Quarter 2**			**Quarter 3**			**Quarter 4**		
		Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24
Soil													
Soil Sample	Pre-Flow <==>						<==>						
Channel Inspection													
Photo Document	Pre-Flow <==>			<==>			<==>			<==>			<==>
Map Points	Pre-Flow <==>									<==>			
Vegetation	Pre-Flow <==>												
Record vegetation at										<==>			
sample sites							<==>						
Photo Monitoring	Pre-Flow <==>												
Photo Document				<==>			<==>						
Channel Topography	Pre-Flow <==>												
Channel Inspection													
Outfall Inspection				<==>			<==>						<==>
Reservoir Inspection	Pre-Flow <==>						<==>						<==>
Photo Document							<==>						<==>
Map Points							<==>						<==>
Water Quality													
Sample Analysis at				<==>			<==>			<==>			<==>
Listed Points	Pre-Flow <==>												

Monitoring Category Monitor Point *Monitor Action*	**Initial Monitoring Baseline Data**	**Year 3**				**Year 4**				**Year 5**			
		Qtr 1	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**
Soil													
Soil Sample	Pre-Flow <==>		<==>						<==>				
Channel Inspection													
Photo Document	Pre-Flow <==>		<==>		<==>		<==>		<==>		<==>		<==>
Map Points	Pre-Flow <==>		<==>				<==>				<==>		
Vegetation	Pre-Flow <==>												
Record vegetation at													
sample sites			<==>						<==>				
Photo Monitoring	Pre-Flow <==>												
Photo Document		<==>		<==>			<==>		<==>		<==>		<==>
Channel Topography	Pre-Flow <==>												
Channel Inspection													
Outfall Inspection			<==>		<==>		<==>		<==>		<==>		<==>
Reservoir Inspection	Pre-Flow <==>		<==>		<==>		<==>		<==>		<==>		<==>
Photo Document			<==>				<==>				<==>		
Map Points			<==>				<==>				<==>		
Water Quality													
Sample Analysis at			<==>		<==>		<==>		<==>		<==>		<==>
Listed Points	Pre-Flow <==>												